

WHAT IS CLAIMED IS:

1. A method for the extraction and purification of zeolite from a zeolite ore containing other mineral phases comprising:

5 preparing a slurry comprising low electrolyte demineralized water and mechanically preprocessed zeolite ore having a mean particle size ranging from about 10 to 40 microns, said slurry having a density of about 5% to 40%, and
10 said slurry having a low electrolyte demineralized water to mechanically preprocessed zeolite ore mass ratio sufficient to substantially suspend any clay fraction of said zeolite ore;

15 subjecting said slurry to mechanical dispersion; allowing said zeolite to settle from said slurry resulting in an upper aqueous fraction and a settled zeolite fraction;
separating said settled zeolite fraction and said
20 upper aqueous suspended fraction; and mixing said settled zeolite fraction with demineralized water to produce a slurried process stream.

2. The method of Claim 1 wherein the zeolite phase
25 of said zeolite ore comprises one or more of the group consisting of clinoptilolite, mordenite, or other naturally occurring zeolite minerals.

3. The method of Claim 1 wherein the zeolite phase of said zeolite ore is substantially clinoptilolite.

4. The method of Claim 1, wherein preparation of the mechanically preprocessed zeolite ore comprises:

physically liberating the various mineral phases, having a range of respective particle sizes, from the natural mineral ore composition, such that the finest mineral phase to be separated has been effectively liberated from other mineral phases;

controlling the size of said mechanically preprocessed zeolite ore particles to optimize the surface to mass ratio of said particles for said mineral phases to be dispersed and suspended over higher bulk density mineral phases;

controlling the size of zeolite mineral phase to be extracted and purified by selecting the intermediate bulk density of said zeolite mineral phase from the lower and higher bulk densities of other mineral phases of the ore composition; and

effecting the size of liberated mineral phases comprising:

crushing, grinding, or milling said natural ore, and

screening liberated mineral phases or mechanically separating said liberated mineral phases.

5. The method of Claim 4, wherein the zeolite phase of said zeolite ore comprises one or more of clinoptilolite, mordenite, or other naturally occurring zeolite minerals.

6. The method of Claim 4, wherein the zeolite phase of said zeolite ore is substantially clinoptilolite.

7. The method of Claim 1, additionally comprising:
5 injecting said slurried process stream into a multistage countercurrent primary separation column at about the midpoint of said primary separation column, said primary separation column having upper, lower and mid-stages;
10 injecting low electrolyte demineralized water into said lower stage of said primary separation column;
extracting an overflow stream of suspended zeolite from said upper stage of said primary separation column; and
15 controlling the injection rate of said slurried process stream and said demineralized water into said primary separation column and the extraction rate of said suspended zeolite such
20 that said demineralized water flows upward at a rate sufficient to suspend said zeolite and such that higher density components of said slurried process stream, having a net settling velocity, flow downward to said lower stage of
25 said primary separation column.

8. The method of Claim 7, wherein the zeolite phase of said zeolite ore comprises one or more of clinoptilolite, mordenite, or other naturally occurring zeolite minerals.

9. The method of Claim 7, wherein the zeolite phase of said zeolite ore is substantially clinoptilolite.

10. The method of Claim 1, wherein forming a slurry, settling the dispersed zeolite phase and removal of the upper aqueous suspended fraction is repeated one or more times.

11. The method of Claim 1, wherein forming a slurry, settling the dispersed zeolite phase and removal of the upper aqueous suspended fraction is either a batch 10 or a semi-continuous process operation.

12. The method of Claim 11, wherein the batch and/or semi-continuous process operation is facilitated, in part, by an electronic process computer device having 15 feedback from said laboratory or process monitoring instruments.

13. The method of Claim 1, additionally comprising: injecting said suspended zeolite from said primary 20 separation column into a secondary separation column, said secondary separation column having an upper and lower portions; injecting low electrolyte demineralized water into said secondary separation column near said 25 lower portion; extracting a fine particle overflow stream from said upper portion; controlling the injection rates of said suspended zeolite and said low electrolyte demineralized 30 water into the mid-section of said secondary

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separation column and the extraction rate of
said fine particle overflow stream such that a
countercurrent flow is established and that
zeolite particles of a desired range of sizes
are not carried into said countercurrent flow;
and

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removing said zeolite particles of a desired range
of sizes and bulk density from said lower
portion of said secondary separation column
wherein the higher bulk density mineral phases
or "heavies" are retained.

14. The method of Claim 13, wherein said low
electrolyte demineralized water is selected using
periodic laboratory bench simulation.

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15. The method of Claim 13, wherein the said
demineralized water is removed for filtration, polishing
demineralization, and recycled for further use in the
process, to avoid unwanted water generation and water
consumption.

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16. The method of Claim 13, wherein the physical
and chemical properties of separated said clay phases and
heavies phase, or tailings, remain substantially
unaltered by the properties of said low electrolyte
demineralized water, to facilitate classification as
25 marketable by-products rather than chemical or hazardous
waste products.

17. The method of Claims 13, wherein the chemical
state of tailings or by-product mineral phases are not
substantially altered.

18. The method of Claim 13, wherein removing zeolite particles from the lower portion of said secondary separation column and controlling the extraction of fine particles in the overflow is achieved 5 by the ratio of said low electrolyte demineralized water injected at the respective locations.

19. The method of Claim 13, wherein the size of fine particles in said overflow are determined by grade sampling or in-line process analysis.

10 20. The method of Claim 13, wherein the said suspended zeolite from said primary separator column is mechanically reprocessed to further reduce particle size prior to injection into said secondary separator column.

15 21. The method of Claim 13, wherein the said suspended zeolite from said primary separator column is processed by magnetic devices to further remove magnetic mineral phases prior to injection into said secondary separator column.

20 22. The method of Claim 19, wherein the fine particle overflow is based, in part, on the analysis of said mineral phases and ratios thereof, by grab sampling or in-line continuous or intermittent analysis using x-ray fluorescence, laser induced breakdown spectroscopy or alternate methods.

25 23. The method of Claim 22, wherein the controlled parameters of said low electrolyte demineralized water injection rates and ratio of respective injection flows at each location are achieved by feedback from the

analysis of said mineral phases and ratios thereof, and facilitated by an electronic process computer device.

24. The method of Claim 23, wherein the high bulk density, low surface to mass ratio, and minimal propensity of electrical double layer of said heavies mineral phases comprise a state that is not effectively suspended or dispersed by the said low electrolyte demineralized water.

25. The method of Claim 24, wherein the effective separation of said zeolite phase being an intermediate bulk density mineral with respect to said clay phase and said heavies or high bulk density mineral phases, is facilitated.

26. The method of Claim 1, wherein the water volume to said mechanically preprocessed zeolite ore mass ratio is selected by laboratory bench simulation.

27. The method of Claim 1, wherein the demineralized water quality is selected by laboratory bench simulation.

20 28. The method of Claim 1, wherein the fraction of clay and other low bulk density minerals are periodically assessed by x-ray diffraction, x-ray florescence, or alternate laboratory methods to select the ratio of demineralized water and mechanically preprocessed zeolite 25 ore.

29. The method of Claim 1, wherein the fraction of clay and other low bulk density minerals are continuously or intermittently assessed using in-line process

monitoring.

30. The method of Claim 29, wherein the in-line process is an x-ray fluorescence or laser induced breakdown spectroscopy analyzer.

5 31. The method of Claim 20, wherein the preferred particle size is determined by repeat laboratory simulation for size reduction, further simulation of the extraction and purification and analysis.

10 32. The method of Claims 1, wherein the low electrolyte demineralized water has a concentration of dissolved minerals that is determined by laboratory or in-line methods of specific ion measurement or by specific conductivity determination.

15 33. The method of Claim 1, wherein the low electrolyte demineralized water has a concentration of dissolved minerals of about 20 to about 200 ppm.

34. The method of Claim 1, wherein the low electrolyte demineralized water has a concentration of dissolved minerals of about 5 to about 20 ppm.

20 35. The method of Claim 1, wherein the mean particle size of said mechanically preprocessed ore ranges from about 10 to about 40 microns.

36. The method of Claim 1, wherein the mean particle size of said mechanically preprocessed ore 25 ranges from about 5 to 20 microns.

37. The method of Claim 1, wherein the mean particle size of said mechanically preprocessed ore

ranges from about 1 to about 10 microns.

38. The method of Claim 20, wherein the said re-processed particle size of said suspended zeolite ranges from about 5 to about 20 microns.

5 39. The method of Claim 20, wherein the said re-processed particle size of said suspended zeolite ranges from about 1 to about 5 microns.

10 40. The method of Claim 1, wherein the said demineralized water is removed for filtration, polishing demineralization, and recycled for further use to avoid unwanted waste generation and water consumption.

41. The method of Claim 1, wherein the volume to mass ratio is determined by continuous or grab sampling, said low electrolyte demineralized water quality.

15 42. The method of Claim 1, wherein the said effective ratio of said low electrolyte demineralized water to said mechanically preprocessed zeolite ore mass is determined manually or predicted by algorithm residing in an electronic process computer.

20 43. The method of Claim 1, wherein the said zeolite phase, having physical properties such as bulk density that are greater than that of clay and similar density mineral phases contributes to a mineral phase separation in said higher purity demineralized water.

25 44. The method of Claim 1, wherein the surface area to mass ratio of the clay and similar fine particles of other mineral phases being greater than the surface area

to mass ratio contributes to a mineral phase separation
in said low electrolyte demineralized water.

45. The method of Claim 40, wherein separation of
said mineral phases contained in said mechanically
5 preprocessed zeolite ore is attained without
contaminating effects of inorganic or organic chemical
additives.

46. A process for extracting and purifying natural zeolite from zeolite ore comprising:

hydrating and mechanically dispersing a starting material to separate out highly hydrated clay
5 content; and

separating a zeolite from contaminants having a higher mass to surface area ratio than said zeolite by use of one or more countercurrent flow separation columns in which the dispersing
10 medium is demineralized water.

47. The process of Claim 46, wherein said starting material comprises a pre-processed feedstock.

48. The process of Claim 47, wherein the pre-processed feedstock is prepared by crushing, milling or
15 grinding a feedstock to obtain a desired average or mean particle size.

49. The process of Claim 47, wherein the average or mean particle size of the pre-processed feedstock is about 10 to 40 microns.

20 50. The process of Claim 46, wherein the zeolite ore comprises one or more of clinoptilolite, mordenite or other naturally occurring zeolite minerals.

51. A process for extracting and purifying natural zeolite from zeolite ore comprising:

5 pulverizing zeolite ore comprising clinoptilolite, mordenite, feldspar, clay, mica and quartz;
mixing the pulverized ore with demineralized water having less than about 50 ppm electrolytes to form a first slurry;
mixing the first slurry in a batch fashion at high speed;
10 allowing the first slurry to settle; and decanting a clay liquid suspension from the settled first slurry to obtain a separated zeolite product.

52. The process of Claim 51, additionally comprising:

15 adding demineralized water having less than about 50 ppm electrolytes to said separated zeolite product;
mixing the demineralized water and the zeolite product to form a second slurry; injecting said second slurry into the mid-section of a separation column;
20 delivering demineralized water having less than 50 ppm electrolytes to the lower section of said separation column;
25 providing a counterflow rate of demineralized water that is sufficient to suspend zeolite and to allow higher density components to settle; and extracting the suspended zeolite from the settled higher density components.
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53. The process of Claim 51, wherein the demineralized water has less than 10 ppm electrolytes.

54. A process for the extraction and purification
of zeolite from a zeolite ore comprising:

mixing demineralized water with a settled zeolite
fraction to produce a slurried zeolite process
5 stream, said settled zeolite fraction being
settled from a mechanically dispersed slurry
comprised of demineralized water and a
mechanically processed zeolite ore having a
mean particle size ranging from about 10 to 40
10 microns, said slurry having a density of about
5% to 40% and a demineralized water to zeolite
ore mass ratio to substantially suspend any
clay fraction of said zeolite ore.

55. A process for separation of mineral phases from a natural mineral ore composition, comprising:

separating the mineral phases from an aqueous slurry or suspension by integrating differential suspension and physical separation principles,
5 said aqueous slurry or suspension comprising mineral phases that have been substantially liberated from natural ore by crushing, grinding or milling and demineralized water
10 with low electrolyte content that sustains a maximum electrical double layer to aid dispersal and separation of said mineral phases according to the extent of hydration.

56. A method for classification of a particulate mineral compound comprising:

5 injecting demineralized water into one or more countercurrent classifying columns comprising an aqueous slurry of the particulate mineral compound to form an ascending demineralized water stream sufficient to amplify differences in particle settling velocity.

57. The method of Claim 56, wherein the one or more 10 classifying columns each have one or more stages, a feed injection port at about the midpoint of said classifying column, a demineralized water injection port below said feed injection port, a cap at such column's topmost edge, and an overflow port below said cap.

15 58. The method of Claim 56, wherein the number, size and/or configuration of the one or more countercurrent classifying columns is tailored to a desired particle size and/or mineral phase.

59. The method of Claim 56, wherein the aqueous 20 slurry in the countercurrent classifying column has a slurry density of about 5% to about 40%.

60. The method of Claim 56, wherein the particulate mineral compound comprises particles possessing an electrical double layer when hydrated in low electrolyte 25 medium and having a range of particle sizes.

61. The method of Claim 56, wherein said particulate mineral compound is a compound comprising particles of a desired range of sizes from a lower

portion of a secondary separation column.

62. The method of Claim 56, wherein the particulate mineral compound is a zeolite compound.

63. The method of Claim 56, wherein the aqueous slurry has a slurry density of 10% to 20%.

64. The method of Claim 56, wherein the demineralized water has a low electrolyte content.

65. The method of Claim 56, wherein the demineralized water has an electrolyte content of less than about 500 ppm.

66. The method of Claim 56, wherein the demineralized water has an electrolyte content of less than about 100 ppm.

67. The method of Claim 56, wherein the demineralized water has an electrolyte content of less than about 50 ppm.

68. The method of Claim 56, wherein the demineralized water has an electrolyte content of less than about 10 ppm.

69. A method for classification of a particulate mineral compound comprising:

introducing an aqueous slurry of said particulate mineral compound slurry into a countercurrent classifying column, said classifying column having one or more stages, a feed injection port at about the midpoint of said classifying column, a demineralized water injection port below said feed injection port, a cap at such column's topmost edge, and an overflow port below said cap;

injecting demineralized water into said countercurrent classifying column at said demineralized water injection port so as to form an ascending demineralized water stream sufficient to amplify differences in particle settling velocity;

separating said particulate compound using the separation effect of said electrical double layer; and

extracting an overflow stream through said overflow port.

70. The method of Claim 69, wherein said particulate mineral compound is a compound comprising particles of a desired range of sizes from a lower portion of a secondary separation column.

71. The method of Claim 69, wherein the particulate mineral compound is a zeolite compound.

72. The method of Claim 69, wherein the aqueous

slurry in the countercurrent classifying column has a slurry density of about 5% to about 40%.

73. The method of Claim 69, wherein the aqueous slurry in the countercurrent classifying column has a
5 slurry density of about 10% to about 20%.

74. The method of Claim 69, wherein the demineralized water has a low electrolyte content.

75. The method of Claim 69, wherein the demineralized water has an electrolyte content of less
10 than about 500 ppm.

76. The method of Claim 69, wherein the demineralized water has an electrolyte content of less than about 100 ppm.

77. The method of Claim 70, wherein the
15 demineralized water has an electrolyte content of less than about 50 ppm.

78. The method of Claim 71, wherein the demineralized water has an electrolyte content of less than about 10 ppm.

79. A method for classification of a particulate mineral compound comprising:

injecting a slurried process stream into a multistage countercurrent primary separation column at about the midpoint of said primary separation column, said primary separation column having upper, lower and mid- stages;

injecting demineralized water into said lower stage of said primary separation column;

extracting an overflow stream of suspended particulate mineral compound from said upper stage of said primary separation column; and controlling the injection rate of said slurried process stream and said demineralized water into said primary separation column and the extraction rate of said suspended particulate mineral compound such that said demineralized water flows upward at a rate sufficient to suspend said particulate compound and such that higher density components of said slurried process stream, having a net settling velocity, flow downward to said lower stage of said primary separation column.

80. The method of Claim 79, additionally comprising:

injecting said suspended particulate mineral compound from said primary separation column into a secondary separation column, said secondary separation column having upper and lower portions;

injecting demineralized water into said secondary separation column near said lower portion; extracting a fine particle overflow stream from said upper portion;

5 controlling the injection rates of said suspended particulate mineral compound and said demineralized water into said secondary separation column and the extraction rate of said fine particle overflow stream such that a countercurrent flow is established and that particles of said particulate mineral compound of a desired range of sizes are not carried into said countercurrent flow; and

10 removing said particles of a desired range of sizes from said lower portion of said secondary separation column.

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81. A process for the extraction and purification of zeolite from a zeolite ore containing other mineral phases comprising:

5 preparing a slurry consisting of demineralized water and zeolite ore having a mean particle size ranging from about 10 to 40 microns, said slurry having a density of about 5% to 40%, said slurry having a demineralized water to zeolite ore mass ratio sufficient to substantially suspend ;

10 subjecting said slurry to mechanical dispersion having a demineralized water to zeolite ore mass ratio to substantially suspend any clay fraction of said zeolite ore;

15 allowing said zeolite to settle from said slurry resulting in an upper aqueous fraction and a settled zeolite fraction;

separating said settled zeolite fraction and said upper aqueous fraction; and

20 mixing said settled zeolite fraction with demineralized water to produce a slurried process stream.

82. The process of Claim 81, further comprising the 25 steps of:

injecting said slurried process stream into a multistage countercurrent primary separation column at about the midpoint of said primary separation column, said primary separation column having upper, lower and mid- stages;

30 injecting demineralized water into said lower stage

of said primary separation column;
extracting an overflow stream of suspended zeolite
from said upper stage of said primary
separation column; and
5 controlling the injection rate of said slurried
process stream and said demineralized water
into said primary separation column and the
extraction rate of said suspended zeolite such
that said demineralized water flows upward at a
10 rate sufficient to suspend said zeolite and
such that higher density components of said
slurried process stream, having a net settling
velocity, flow downward to said lower stage of
said primary separation column.
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83. The process of Claim 81, further comprising the
steps of:
injecting said suspended zeolite from said primary
separation column into a secondary separation
20 column, said secondary separation column having
upper and lower portions;
injecting demineralized water into said secondary
separation column near said lower portion;
extracting a fine particle overflow stream from said
25 upper portion;
controlling the injection rates of said suspended
zeolite and said demineralized water into said
secondary separation column and the extraction
rate of said fine particle overflow stream such
30 that a countercurrent flow is established and
that zeolite particles of a desired range of

sizes are not carried into said countercurrent flow; and
removing said zeolite particles of a desired range
of sizes from said lower portion of said
secondary separation column.
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84. The process of Claim 81, wherein the zeolite phase of said zeolite ore is substantially clinoptilolite.

10 85. The process of Claim 82, wherein the zeolite phase of said zeolite ore is substantially clinoptilolite.

86. The process of Claim 83, wherein the zeolite phase of said zeolite ore is substantially clinoptilolite.

15 87. The process of Claim 81, wherein the zeolite phase of said zeolite ore comprises one or more of the group consisting of clinoptilolite, mordenite, or other naturally occurring zeolite minerals.

20 88. The process of Claim 82, wherein the zeolite phase of said zeolite ore comprises one or more of the group consisting of clinoptilolite, mordenite, or other naturally occurring zeolite minerals.

25 89. The process of Claim 83, wherein the zeolite phase of said zeolite ore comprises one or more of the group consisting of clinoptilolite, mordenite, or other naturally occurring zeolite minerals.

90. A method for separation of mineral phases from a natural mineral ore composition, said mineral phases having inherent variations in hydration properties, and resulting in differential suspension in a aqueous slurry or suspension, comprising:

crushing, grinding, or milling said natural ore to substantially liberate said mineral phases; preparing an aqueous slurry or suspension in demineralized water wherein the low electrolyte content sustains a maximum electrical double layer to aid dispersal and separation of said mineral phases according to extent of hydration; and separating said mineral phases by integrating the effect of differential suspension and physical separation principles.

91. A composition prepared by a process comprising:
preparing an aqueous slurry of said particulate
mineral compound, said aqueous slurry having a
slurry density of 5% to 40%;
5 introducing said slurry into a countercurrent
classifying column, said classifying column
having one or more stages, a feed injection
port at about the midpoint of said classifying
column, a demineralized water injection port
10 below said feed injection port, a cap at such
column's topmost edge, and an overflow port
below said cap;
introducing demineralized water into said
countercurrent classifying column at said
15 demineralized water injection port to form an
ascending demineralized water stream;
separating said particulate compound using the
separation effect of said electrical double
layer; and
20 extracting an overflow stream through said overflow
port.

92. A composition prepared by a process comprising:
preparing a slurry consisting of demineralized water
and zeolite ore having a mean particle size
ranging from about 10 to 40 microns, said
5 slurry having a density of about 5% to 40%,
said slurry having a demineralized water to
zeolite ore mass ratio sufficient to
substantially suspend ;
subjecting said slurry to mechanical dispersion
10 having a demineralized water to zeolite ore
mass ratio to substantially suspend any clay
fraction of said zeolite ore;
allowing said zeolite to settle from said slurry
resulting in an upper aqueous fraction and a
15 settled zeolite fraction;
separating said settled zeolite fraction and said
upper aqueous fraction; and
mixing said settled zeolite fraction with
demineralized water to produce a slurried
20 process stream.

93. A composition prepared by a process comprising:
crushing, grinding, or milling a natural mineral ore
to liberate mineral phases that have inherent
variations in hydration properties;
5 preparing an aqueous slurry or suspension of the
natural mineral ore in demineralized water
wherein the low electrolyte content sustains a
maximum electrical double layer to aid
dispersal and separation of mineral phases in
10 the natural mineral ore according to extent of
hydration; and
separating said mineral phases by integrating the
effect of differential suspension and physical
separation principles.